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FEEDING EXPERIMENTS WITH MIXTURES OF FOODSTUFFS IN UNUSUAL PROPORTIONS*

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Ever since Magendie[1] announced, in 1816, that the protein group of foodstuffs represents an indispensable component of the dietary of the higher animals, students of nutrition have been interested in the part played by the other nutrients that commonly enter into our food intake. Are fats or carbohydrates or both equally essential for successful nutrition? We pointed out some time ago that the reason why there is no available information respecting the actual requirement of the healthy mammal for fat is attributable to the experimental difficulties heretofore inherent in its solution.[2] Until the significance of the accessory food factors now known as vitamines was appreciated studies of the physiological value of mixtures of different foodstuffs, etc., were liable to lead to failure and erroneous conclusions, not because the supply of energy or protein or salts was inadequate but because other unrecognized and unidentified essentials were lacking.

Since it has become possible, by taking account of these various newly appreciated properties of foods, to devise rations in which essentially one factor at a time may be altered, the investigation of the rôle of the individual nutrients has become more promising. Accordingly we have already succeeded in raising young animals (albino rats) from an early age to adult size on diets which were exceptionally poor in fats.

The food mixtures consisted of the residues from extracted lean meat as a source of protein, starch, inorganic salts, together with small quantities of alfalfa and dried brewery yeast furnishing the vitamins A and B. Analyses of the rations consumed indicated that the maximum intake of fat at any time did not exceed 0.3 per cent of the food eaten. Inasmuch as all the animals starting on the diet with a body weight of approxi-

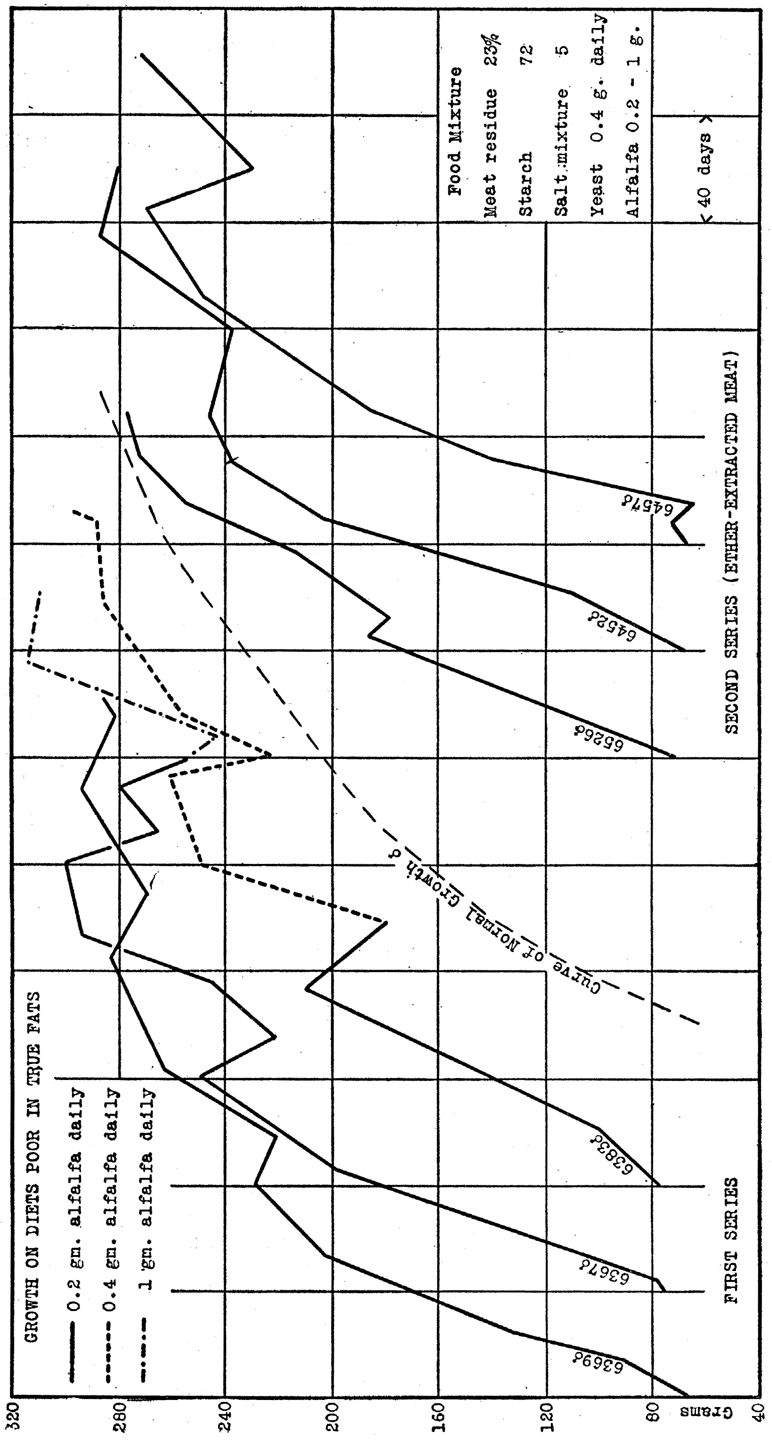
GROWTH ON DIETS POOR IN TRUE FATS
0.2 gm. alfalfa daily
0.4 gm. alfalfa daily
1 gm. alfalfa daily
Food Mixture
Meat residue 23%
Starch 72
Salt mixture 5
Yeast 0.4 g. daily
Alfalfa 0.2 - 1 g.
< 40 days >
6369♂
6367♂
6383♂
6526♂
6452♂
6457♂
Curve of Normal Growth ♂
FIRST SERIES
SECOND SERIES (ETHER-EXTRACTED MEAT)
Grams
320
280
240
200
160
120
80
40

CHART 1

mately 70 gm. have quadrupled their weight within the usual time, and appear as well nourished as companion rats on diets containing liberal portions of butter fat or lard, we cannot avoid the conclusion that if true fats are essential for nutrition during growth the minimum necessary must be exceedingly small. Drummond[3] has also secured some success on diets practically devoid of fat with rats receiving an approximate daily intake of neutral fat amounting to 14 mg. He too concludes that unless this minute amount of fat plays as important a rôle in the metabolism of the organism as do the minute quantities of such substances as the accessory factors, it is reasonable to suggest that pure fats are dispensable constituents of the mammalian diet.

The outcome of all these investigations leads one to question seriously the contentions made, particularly during the recent war, that fats as such play some unique rôle in maintaining well-being; and further, as Maignon[4] supposes, that they play an important rôle in the utilization of protein,—a rôle which carbohydrates are powerless to fill. On the other hand the demonstrations afforded by our experiments should not be construed to minimize the great value of fats as a source of energy in the usual dietary, as well as their peculiar advantages in culinary procedures.

As we have recently pointed out[5] carbohydrates are ordinarily regarded as indispensable components of the food intake. This belief is based on the presence of more or less carbohydrate in the food mixtures consumed by man and the higher animals, and the fact that sugar is a constant constituent of the blood. It is almost universally taught that carbohydrate is essential for the proper metabolism of fats in addition to any other functions that it may perform in the body; for ketone substances may be excreted in diabetes when sugar fails to be burned up in the normal manner in the organism. On the other hand it is assumed that glucose can be formed from the protein molecule or its amino-acids under certain conditions in the metabolism so that one could conceive carbohydrate to become available for the special needs of fat metabolism and other purposes without being specifically furnished as *preformed* carbohydrate in the diet. The current opinion, summarized by one recent writer,[6] maintains that "carbohydrates are the most economical of the foodstuffs, both physiologically and financially. They are the greatest sparers of protein. Ingestion of fat has for its object the relieving of the intestine from excessive carbohydrate digestion and absorption. Ingestion of fat in too large quantities leads to digestive disturbances, and if carbohydrates are entirely abandoned, to acetonuria."

Not long ago we announced that rats receiving a diet in which the amount of digestible carbohydrate was at most exceedingly small can grow from an early age to adult size. The rations which we fed included pro-

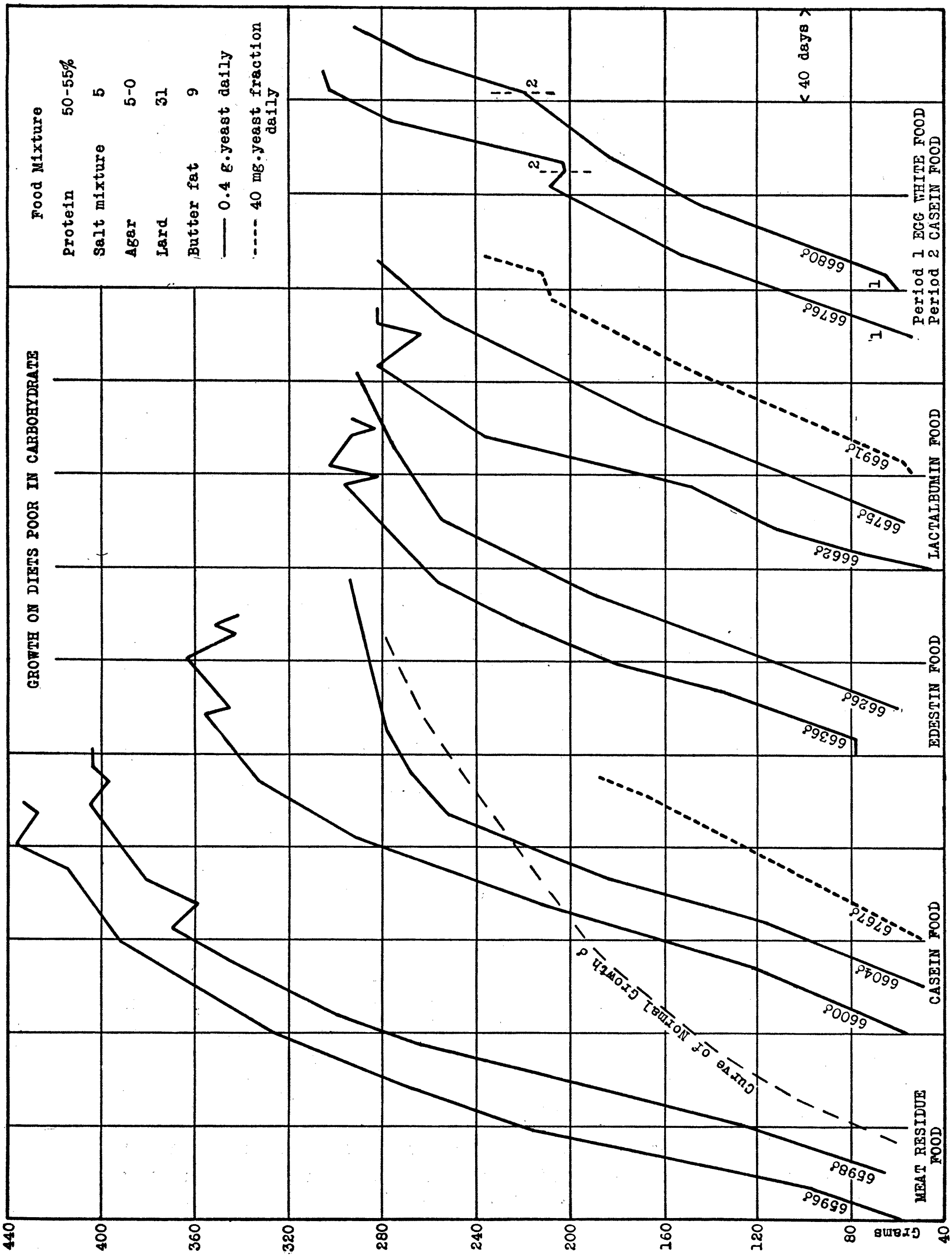
GROWTH ON DIETS POOR IN CARBOHYDRATE
Food Mixture
Protein 50-55%
Salt mixture 5
Agar 5-0
Lard 31
Butter fat 9
0.4 g. yeast daily
40 mg. yeast fraction daily
< 40 days >
Period 1 EGG WHITE FOOD
Period 2 CASEIN FOOD
LACTALBUMIN FOOD
EDESTIN FOOD
CASEIN FOOD
MEAT RESIDUE FOOD
1
2
6680♂
6676♂
6691♂
6675♂
6662♂
6626♂
6638♂
6757♂
6604♂
6600♂
6598♂
6596♂
Curve of Normal Growth ♂
Grams
40
80
120
160
200
240
280
320
360
400
440

CHART 2

tein—casein, edestin, or lean beef which had been thoroughly extracted with boiling water—inorganic salts, agar-agar, lard, butter fat and 0.4 gm. daily of dried brewery yeast furnishing vitamin B. This amount of yeast can scarcely be regarded as a significant source of available carbohydrate. Success was likewise attained in experiments in which no agar-agar was introduced. In the latter case the only obvious sources of preformed carbohydrate aside from the yeast employed were such carbohydrate impurities as might still adhere to the protein preparation fed.

The newest experiments conducted with materials from which the carbohydrate was even more rigorously excluded have not yet been brought to a conclusion; but in these also considerable growth at a normal rate has already been attained. It will be observed that the dietary conditions under which this series of nutrition experiments has been conducted are such as are reputed to lead to ketosis and ketonuria in human subjects.

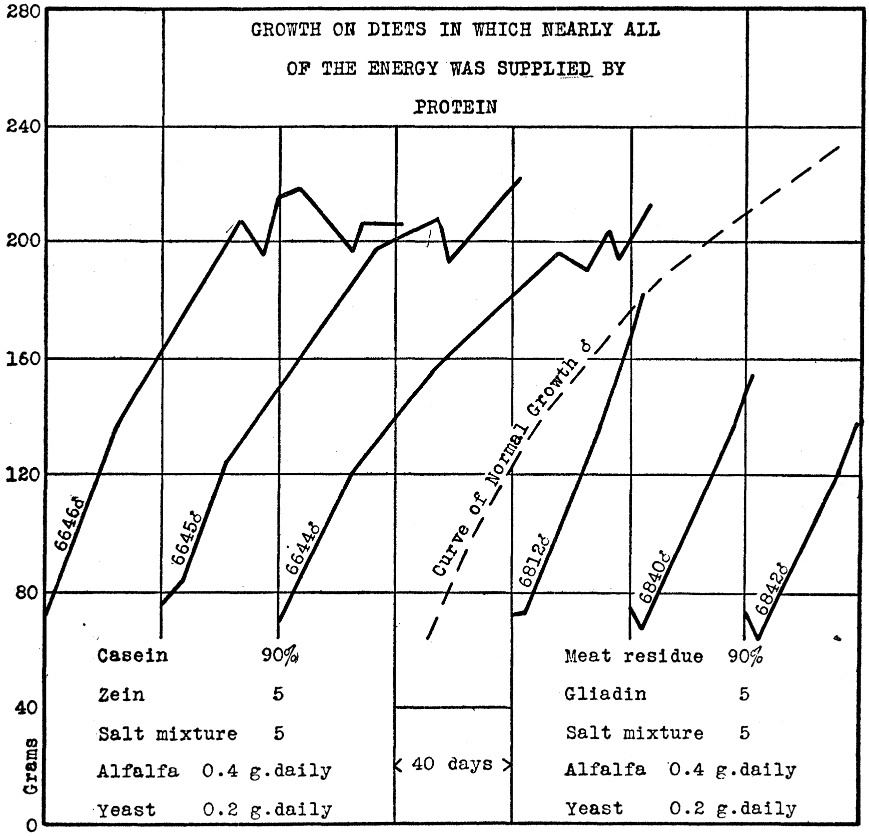

CHART 3

In view of the success of the foregoing experiments we have investigated the possibility of nourishing animals on food mixtures from which both carbohydrates and fats have been eliminated as far as possible. The attempts have thus far resolved themselves essentially into feeding a diet of which more than 90 per cent consists of protein, along with 5 per cent of inorganic salts and vitamins in the form of small daily doses of dried alfalfa and brewery yeast.

Although it has been demonstrated by experiments of Pflüger[7] that a carnivorous animal can be kept alive and maintained in activity of considerable periods on an exclusive diet of meat, it has been stated that omnivora and herbivora cannot survive on such a ration. In our own trials[8] in which the vitamin-bearing substances, representing 4–8 per cent of the food eaten, were the only noteworthy sources of either fat or carbohydrate, a number of animals have already approximately tripled their size, growing at essentially a normal rate for their species.

In all of the experiments on the unusual diets reported in this communication the protein content of the food mixtures was unusually high. Accordingly the question may well be raised whether a comparatively high protein content in the dietary during growth is not actually advantageous rather than detrimental as has been suggested by certain writers. Whether animals will attain full adult size and normal function on diets furnishing protein as the almost exclusive source of energy and tissue substance cannot be foretold at the present time. In any event the experience gained from these newest studies raises a number of important problems of physiological interest and also suggests new possibilities of investigation from novel standpoints.

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[1] Magendie, F., *Ann. Chim. Phys.*, **3**, 1816 (66).

[2] Osborne, T. B., and Mendel, L. B., *J. Biol. Chem.*, **45**, 1920 (145).

[3] Drummond, J. C., *Proc. Physiol. Soc.*, *J. Physiol.*, **54**, 1920 (xxx).

[4] Maignon, F., *Récherches sur le rôle des graisses dans l'utilisation des albumnoides.* Lyon, 1919.

[5] Osborne, T. B., and Mendel, L. B., *Proc. Soc. Exper. Biol. Med.*, **18**, 1921 (136).

[6] Lusk, G., *The Science of Nutrition.* Philadelphia, 1917, p. 288.

[7] Pflüger, E., *Pflüger's Arch.*, **50**, 1891 (98); **77**, 1899 (425).

[8] A preliminary account of this is given by Osborne, T. B., and Mendel, L. B., *Proc. Soc. Exper. Biol. Med.*, **18**, 1921 (167).